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NCRP REPORT No. 54

MEDICAL RADIATION EXPOSURE OF PREGNANT AND POTENTIALLY PREGNANT WOMEN

NCRP

National Council on Radiation Protection and Measurements

[For detailed information on the availability
of this and other NCRP Reports see page 28]

NCRP REPORT No. 54

MEDICAL RADIATION EXPOSURE OF PREGNANT AND POTENTIALLY PREGNANT WOMEN

Recommendations of the
NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

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Preface

For a number of years the NCRP has included in its recommendations a statement suggesting certain limitations on the time, relative to the menstrual cycle, when pregnant or potentially pregnant women might be subjected to x-ray diagnostic examinations of the abdomen or pelvis. Some medical practitioners have called attention to practical difficulties in implementing the recommendation and raised questions that might have medico-legal significance. As a result, the NCRP decided to reexamine the question, especially in view of some of the analyses of diagnostic exposure data that have been made since the last NCRP statement on this topic was published. Other organizations, such as the American College of Radiology and the Bureau of Radiological Health of the Food and Drug Administration, have also been examining the question.[1] The present report recognizes that sensitivity to ionizing radiations is greatest during intrauterine development and that the probability of causing different types of effects varies with the stage of pregnancy and with the dose. The option of scheduling diagnostic examination of the abdomen or pelvis of pregnant or potentially pregnant women on the basis of this consideration is left to the attending physician. However, the report stresses that delay of an examination for dose reduction is warranted only if it can be done without jeopardy to the medical care of the patient and/or unborn child.

The present report was prepared by the Council's Ad Hoc Committee on Exposure of Potentially Pregnant Women in Diagnostic Radiology. Serving on the Committee during the preparation of this report were:

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[1]See, for example, the news report, "New Policy on Radiation of Women Told" (ACR Bulletin **32**, No. 12, 7, 1976) and the announcement, "Medical Radiation Exposure of Women of Childbearing Age" (Federal Register, December 15, 1975, page 58151).

The Council wishes to express its appreciation to the members and consultants for the time and effort devoted to the preparation of this report.

Warren K. Sinclair
President, NCRP

Bethesda, Maryland
April 22, 1977

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1. Introduction

In 1966, the International Commission on Radiological Protection (ICRP) published recommendations advising the avoidance or postponement of certain diagnostic radiation exposures of pregnant or potentially pregnant patients (ICRP, 1966). These applied especially in situations where the diagnostic procedure was considered as elective or not of immediate benefit to the patient. NCRP Report No. 39 provides a definition of an "elective procedure" which is appropriate for the purposes of this report: an examination of the abdomen and pelvis which does not contribute to the diagnosis or treatment of a woman in relation to her immediate illness (NCRP, 1971). In 1968 and again in 1971, the National Council on Radiation Protection and Measurements (NCRP) issued recommendations comparable to those of the ICRP (NCRP, 1968, 1971) except that in 1971 the NCRP recommended a restriction of examinations to the first 14 days of the menstrual cycle, as compared with the first 10 days recommended previously.

Since the 1971 recommendations were issued, there has been considerable discussion of the problem in the literature (Warrick, 1973a, 1973b; World Medical News, 1972; Rugh, 1971; Boice and Burnett, 1973; Brent and Gorson, 1972; Brown *et al.*, 1974; Oppenheim *et al.*, 1975), in various forums of medical and scientific societies, and by various committees. In addition, the question has been receiving consideration by the ICRP and NCRP in connection with the updating of their 1966 and 1971 reports.

In the United States, in addition to the NCRP, the American College of Radiology (ACR), in particular, is concerned with the periodic updating of its guides for radiologists and the physicians who refer patients for radiological examinations (American College of Radiology, 1971). Also, the Bureau of Radiological Health (BRH) of the Food and Drug Administration is concerned with the problem in its role as the responsible federal agency.

Because of the importance of the questions raised, and the practical difficulties involved in screening patients for early pregnancy, the NCRP determined to re-study the problem. As a result of this study, the NCRP has decided to clarify its previous recommendations regarding the medical radiation exposure of pregnant and potentially pregnant women.

This revised recommendation, given in Section 3, should be regarded as tentative and will be subject to further evaluation by the NCRP as

NCRP Report No. 39 undergoes revision. Comments on the revised recommendation will be useful in this further evaluation and are solicited.

Tentative conclusions regarding the effects of small doses of x radiation on the human embryo-fetus must be derived with great uncertainty from human experience and/or animal experiments involving relatively large doses of radiation usually given at high dose rates. Most of the evidence regarding the leukemogenic and carcinogenic effects of diagnostic x-ray exposure on the embryo-fetus comes from epidemiological studies, the results of which are inconsistent or contradictory (Miller, 1975); their interpretation is subject to some debate. Hence, in the case of the low doses normally encountered in diagnostic radiology or nuclear medicine diagnostic procedures, it is difficult to determine with precision either the magnitude or the nature of the radiogenic cancer risk to the embryo-fetus during the various stages of gestation (Miller, 1974).

It can be stated that no radiologic examination should be carried out unless there is a significant medical need for such examination at that time. It may also be stated that no radiological examination for which there is a significant medical need should be denied a patient, even if she is pregnant, for the risk to the patient of not having an indicated examination is also an indirect health risk to the embryo-fetus. However, there may be exceptions to this general thesis. The need for radiological examinations covers the entire spectrum of necessity, and health practitioners may, and often do, disagree as to the importance of a given examination in a given situation.

There is presumably a radiation dose level below which most experts would agree that the risk of any radiation injury from a radiological examination (such as a routine chest x ray) is so small that it would be offset by any slight medical benefit. There is also a level, presumably, above which the risk of the radiological procedure is so great that it should not be carried out except to counteract a life-threatening situation (such as the radiation treatment of cancer). Individual experts will differ if asked to numerically define these levels, and they may draw different conclusions in trying to compare the risks with the benefits in a given situation because both are so often nonquantifiable or at least illdefined.

The NCRP recognizes that any general recommendation it makes regarding the medical radiation exposure of women having child-bearing capacity can serve only as a guide that may be modified in specific instances according to the judgment of the patient's physician and the consulting expert.

2. Discussion of Recommendations

A summary of the potential effects of embryonic and fetal irradiation is included in NCRP Report No. 53, *Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally Exposed Women* (NCRP, 1977). Much of the discussion included in that report is also relevant to the subject of this report.

2.1 Factors to be Considered in the Case of Women Who May be Pregnant

The major difference between this Report and NCRP Report No. 53 is consideration of the different circumstances under which the embryo-fetus is irradiated and consideration of the offsetting risk that the medical welfare of both the expectant mother and her unborn child may be jeopardized if the indicated radiological examinations are *not* carried out. In the case of occupational radiation exposure of pregnant workers, the embryo-fetus is considered to be a member of the general population that, perforce, must accompany its mother to work and thus receive an incidental radiation exposure. By contrast, the embryo-fetus of the pregnant patient undergoing radiological examinations is a clear-cut first-party or second party potential beneficiary. If, in the judgment of the attending physician, protection of the patient's health requires a radiological examination to be carried out at a specific time, and if the examination is carried out with adequate equipment and careful technique, then the potential benefit to the health of the patient and/or the embryo-fetus will, in most cases, outweigh the potential deleterious effects of the irradiation. This conclusion is based on the finding that fewer than 1 in 1,000 of all *radiographic* examinations (not including fluoroscopy) will, if carried out with good equipment and careful technique, subject the embryo-fetus to radiation doses of 1 rad or more (BRH, 1973). At dose levels below one rad, the probability of detectable effect induced by such exposures is so small as to be outweighed by any significant medical benefit.

Radiographic, fluoroscopic, or nuclear medicine examination may, on occasion, alone or in combination, deliver accumulated doses exceeding 1 rad to the uterus. A few animal experiments suggest the possibility of deleterious effect on the embryo from doses of radiation perhaps as low as 10 rad (Brent and Gorson, 1972; Russell, 1957). It is prudent to assume that effects, even though they have been undetectable in experiments to date, can occur at lower doses. Both the NCRP and the ICRP have recommended previously that "elective" examinations of the lower abdomen and pelvis of fertile women be restricted to the early part of the menstrual cycle (NCRP, 1968; NCRP, 1971; ICRP, 1966), at which time the probability that the patient may be pregnant is extremely low.

In the United States, only a few hospitals have adopted any formal scheduling procedure for x-ray examinations of the lower abdomen of such women with regard to the phase of the menstrual cycle (Boice and Burnett, 1973). Even in England, which in 1972 adopted the so-called "10-day rule" as part of its Code of Practice (Radioactive Substances Advisory Committee, 1972), progress in implementing it has been slow (Saxton, 1975). This is probably due in part to the very low frequency of truly "elective" examinations that are postponable and, in part, to the many practical problems in implementing such a policy.

2.1.1 *Dose Considerations*

A number of epidemiological studies involving diagnostic x-ray exposures demonstrate an increased incidence of leukemia and other cancers in prenatally (or preconceptionally) irradiated children leading to estimates of excess risk of between 1 in 1,000 to 1 in 10,000 per rad for the first ten years of life (Graham *et al.*, 1966; Stewart and Kneale, 1970; Jablon and Kato, 1970; Oppenheim *et al.*, 1974; Reekie *et al.*, 1967). There appears to be some evidence that the risk is greatest for prenatal irradiation during the second and third trimesters of pregnancy (Graham *et al.*, 1966). However, most of these studies suffer from uncertainties in dosimetry and are in doubt because of possible selection factors, namely that the examinations were done for medical reasons that did not apply to the control population. The results are negative when selection was *not* a factor in a hospital study (Oppenheim *et al.*, 1974) and in a study of children exposed *in utero* to much higher doses of radiation from the atomic bomb (Jablon and Kato, 1970). Although there are various possible explanations for these contradictions, there is still debate about the interpretation of all the studies on humans and hence about whether prenatal exposure to small doses of radiation can be oncogenic.

Thus far, experimental attempts to increase cancer incidence by small doses of radiation to fetuses of animals have failed (NCRP, 1977).

Both animal experiments and data on humans indicate that, besides the total dose, other radiation factors, such as dose rate, fractionation, and linear energy transfer (LET) are of considerable importance in determining the effect on the embryo. Protracted x or gamma irradiation, or small fractions of low-intensity x or gamma radiation, cause considerably less damage than does the same dose applied as acute x irradiation on any given day during major organogenesis (Russell *et al.*, 1960; Brent 1971). This is probably due to the small size of the dose being received during the critical period for any given developmental process. These discussions therefore apply solely to the low-LET radiation and the dose rates usually encountered in diagnostic radiology and nuclear medicine.

The lowest intrauterine radiation "dose" that has indisputably been associated with an effect in man was 10–19 rad in air to the mother (Miller and Mulvihill, 1976). The effect, small head circumference, was observed in Hiroshima, where the radiation consisted of 20 percent neutrons and 80 percent gamma radiation, but not in Nagasaki, where exposure to neutrons was negligible (Auxier, 1975). Thus the exposure that was associated with the effect was *not* comparable to that arising in medical radiation usage. In addition, in the case of the Hiroshima atomic bomb survivors, radiation may have combined with other influences, such as malnutrition or infection, which were perhaps greater in Hiroshima than in Nagasaki (Miller and Mulvihill, 1976).

Animal experiments indicate that the relatively greater hazard from high dose rate, low-LET radiation to a surviving conceptus occurs during the period of major organogenesis. The lowest dose that was included in experiments involving this period, 25 rad, yielded measurable radiation effects in 0 to 20 percent of the survivors, depending on the abnormality (Russell, 1957; Wilson *et al.*, 1953). In one of the low-dose experiments, observation was restricted to the skeletal system. The dose-effect curves for doses of 25 rad and greater were of different shapes for different skeletal anomalies. As indicated above, projections to lower levels indicate that the overall effect on the skeleton of doses of less than 10 rad administered at that stage of development would probably be indistinguishable from normal incidence (Russell, 1957).

Experiments have been in progress for several years, and are continuing at the time of preparation of this report, involving the irradiation of embryos to dose levels from 5-40 rad during the pre-implantation or early organogenic period in rats and mice (Brent, 1977). Preliminary results show a questionable increase in malformation rate after 20 rad given on day 9½, (organogenesis), but no significant decrease in the litter size,

resorption rate, mean fetal weight, nor significant increase in gross congenital malformations at dose levels of 15 rad or less. However, it would be premature to draw definitive conclusions from these ongoing experiments.

Although the most conservative assumption from the point of view of risk estimation would be a straight-line dose-effect relationship for radiation-induced malformation, actual findings, as well as theoretical considerations, make this unlikely. Thus, there are several specific abnormalities in the mouse that are induced with 100 percent incidence by 300 rad, but that are not found at all following irradiation with 200 rad (Russell, 1954). Moreover, since a malformation presumably derives from radiation damage to more than a single cell, linear dose-effect curves would not be expected.

2.1.2 *Timing Considerations*

Animal experiments have shown that irradiation during the preimplantation period generally produces an all-or-none effect, i.e., either very early embryonic death (pre- or immediately post-implantation) is caused, or there is apparent normalcy (including growth rate, fertility, and longevity) of survivors (Russell *et al.*, 1960; Russell, 1954). In addition, induction of sex-chromosome loss by early zygotic irradiation (leading to XO individuals) has been demonstrated (Russell and Montgomery, 1966). The increased frequency of either early embryonic death or sex-chromosome loss cannot be detected in experiments of manageable size at the low doses encountered in competently executed diagnostic radiology. The time between implantation and the beginning of major organogenesis, which, in humans, is over a week in duration, may also be relatively insensitive. However, slight increases in malformation frequency have been found in the mouse (Russell, 1954) and growth retardation has been found in the rat after irradiation between implantation and the beginning of organogenesis (Brent and Gorson, 1972).

Therefore, if one wishes to avoid any risk of increasing the incidence of malformation and/or growth retardation by attempting to schedule examinations for times when such effects presumably are not induced, one would have to choose the period of pregnancy before implantation, or postpone the examination until after birth, or at least until after the period of major organogenesis (12 or more weeks after the last menses). On the other hand, the incidence of radiation-induced very early embryonic death and undetectable abortion is presumed to be highest in the preimplantation period in humans as it is known to be in laboratory animals.

At dose levels below 10 rad or so, it would not be easy to determine, even in laboratory animals, the actual magnitude of these risks for each of the periods in question. If one attempts to rely on scheduling as a means to avoid a specific effect occurring in the potential embryo-fetus, one must first decide which of the various hazards one is willing to accept. If one makes the judgment that minimization of the risk of malformations and growth retardation is more important than minimization of the risk of possibly increased incidence of very early, undetectable embryonic death, then one could schedule "elective" examinations of the abdomen and pelvis during the first twenty-one days of the menstrual cycle. Noting that the excess risk of adverse effects arising from doses below 10 rad probably is not statistically detectable in experiments involving manageable numbers of animals, one must decide on a level above which scheduling is indicated. Doses below 5 rad to the human embryo-fetus are considered by many to represent an acceptable risk when compared to the potential medical benefit of the examination to the patient.

In practice, very rarely does a diagnostic examination, including fluoroscopy, result in a dose to the uterus as high as 5 rad. Therefore, at the 5 rad level, it would rarely be necessary to schedule an *elective* examination of a patient. Others, however, may argue for a lower dose to the embryo-fetus above which scheduling of elective abdominal and pelvis examinations should be required (Reekie *et al.*, 1967). Regardless of the dose level one chooses for subsequent action, a series of decisions will be required. An example of the kind of decision tree one would have to follow is outlined in Figure 1. In any case, however, the physician referring a patient for radiological examination of the abdomen or pelvis should elicit from the patient information concerning known or suspected pregnancy. A guide for documenting such information is given in Figure 2.

2.2 Factors to be Considered When Pregnancy is Discovered After Medical Radiation Exposure of the Fetus

There have been numerous occasions when, following a radiological procedure, a patient has discovered that she was pregnant at the time of the examination and she or her family or her physician has become concerned over the possible hazards (Brent and Gorson, 1972).

When the question of whether the pregnancy should be terminated arises, it would seem that the patient, with the advice of her attending physician and consultant, should make the ultimate decision. The "ad-

DECISION GUIDES FOR SCHEDULING OR POSTPONING ELECTIVE EXAMINATIONS OF THE ABDOMEN OR PELVIS OF WOMEN OF CHILD-BEARING CAPACITY

The following guideline is for physicians scheduling or postponing *elective* examination of the abdomen or pelvis of women of childbearing capacity. An *elective* examination is one that is *not* of immediate importance to the patient's health and can be postponed to term if the patient should prove to be pregnant, without significant risk to the health of the patient or her conceptus. The examinations of interest are those listed in Group C (high dose group) of Table I. See also the guides given in Fig. 2 for requesting radiological consultations.

I. Is the examination of the abdomen or pelvis an *elective* procedure for the patient under consideration?

A. No. ☐ Go to II.

B. Yes. ☐ Go to IV.

II. Is the patient pregnant?

A. No. There is no chance of an unsuspected pregnancy. ☐ Proceed with the examination. Advise patient to avoid the risk of pregnancy until after two months after the examination.

B. Yes, or pregnancy cannot be ruled out. ☐ Advise the patient that medical judgment indicates that the need for the examination outweighs the possible slight risk to the embryo or fetus. Go to III.

III. Can the examination be modified so as to reduce the dose to the uterus (embryo or fetus if present)?

A. No. ☐ Proceed with the examination.

B. Yes. ☐ Proceed with the modified examination.

IV. How many days after the onset of the last menses would the examination be performed?

A. 0–14 days. ☐ Proceed with examination. Advise the patient to avoid pregnancy for two months.

B. 15 days or more. ☐ Postpone examination until menstruation ensues. If patient proves to be pregnant, postpone the examination until term.

Fig. 1. Example of decision tree that might be employed in considering an elective examination of the abdomen or pelvis of a woman of childbearing capacity.

vice" should include a recommendation by the physician in her case and not merely the statistics for her analysis and decision. To assist her in arriving at her decision, however, it is important that her physician and/or the radiologist advise her of the risks of allowing the pregnancy to continue to term and the alternative risk of an abortion. The patient should be informed that from 4-6 percent of all babies are born with varying degrees

TABLE 1—*Estimated Dose to the Ovaries (Uterus)*
[Expressed in millirads per radiographic examination][a]

Type of Examination	Estimated Mean Dose BRH[b]	ICRP[c]	UNSCEAR[d]	Reported Range[e]
A. *Low Dose Group*				
Dental	—[f]	<10	0.06	0.03 to 0.1
Head, Cervical Spine	<0.5	<10	<10	<0.5 to 3
Extremities	<0.5	<10	<10	<0.5 to 18
Shoulder	<0.5	<10	—[f]	<0.5 to 3
Thoracic Spine	11	<10	—[f]	<10 to 55
Chest (Radiographic)	1	—[f]	2	0.2 to 43
Chest (Photofluorographic)	3	<10	3	0.9 to 40
Mammography	—[f]	—[f]	<10	
B. *Moderate Dose Group*				
Upper G.I. Series	171	150	—[f]	5 to 1230
Cholecystography / Cholangiography	78	150	120	14 to 1600
Femur (distal)	—[f]	50	1	1 to 50
C. *High Dose Group*[a]				
Lumbar spine	721	400	410	20 to 2900
Lumbosacral spine			340	73 to 1780
Pelvis	210	250	230	40 to 1600
Hip and femur (proximal)	124	500	240	53 to 1000
Urography, I.V. or retrograde pyelogram	588	700	590	50 to 4000
		800	520	85 to 4000
Urethrocystography	—[f]	1500	—[f]	200 to 3000
Lower G.I. Tract (Barium Enema)	903	800	870	20 to 9200
Abdomen	221	500	210	18 to 1400
Abdomen (Obstetric)	—[f]	1000 (fetal)	300	110 to 1600
Pelvimetry	—[f]	4000 (fetal)	620	160 to 4000
Hysterosalpingography	—[f]	·1200	1270	200 to 6700

[a]Figures are dose estimates to the ovaries for the complete radiographic examination, but not including fluoroscopy. The actual doses to the embryo (uterus) in Group C would be expected to be typically 25–50% greater than the tabulated dose for ovaries (Rosenstein, 1976). The use of fluoroscopy could further increase the dose to the embryo by appreciable amounts.

[b]Bureau of Radiological Health, FDA, see BRH (1976).

[c]International Commission on Radiological Protection, see ICRP (1970).

[d]United Nations Scientific Committee on the Effects of Atomic Radiation, see UNSCEAR (1972).

[e]BRH (1976), ICRP (1970), UNSCEAR (1972) and Lindell and Dobson (1961) combined. The upper limits in the ranges shown are the maximum reported in the cited literature and therefore, in most cases, are much higher than the expected dose to the embryo-fetus for an average size woman when current standards of good radiological practice are followed. The mean values given in column 2 (BRH) are probably the best estimate of mean ovarian doses in the United States at the present time. See BRH (1976) for a more detailed report on the distribution of doses to the ovaries.

[f]No data. See other columns for estimates of mean dose.

GUIDE FOR THE RADIOLOGIST AND FOR THE REFERRING PHYSICIAN REGARDING REQUESTS FOR RADIOLOGICAL CONSULTATION OF WOMEN OF CHILDBEARING CAPACITY

1. Every consultation request form for a nuclear medicine procedure or for a diagnostic x-ray examination of the *abdomen* or *pelvic area* of women of reproductive potential should carry a notation that the possibility or knowledge of pregnancy has been considered and the consultation is being requested after this consideration.

2. In cases of known pregnancy the attending physician is encouraged to consult with the radiologist in determining the extent of the examination. It is recognized that nuclear medicine or diagnostic x-ray examinations may deliver maximum information and be very thorough and detailed or be the minimum required to answer a specific question at the risk of losing some useful information. The physician's judgment should be utilized in making the appropriate decision as to the examination procedures.

3. In cases where pregnancy is not suspected, the patient should be advised that she should not run a risk of pregnancy until two months after the examination of the *abdomen* or *pelvis* has been performed.

SAMPLE OF INFORMATION SHEET FOR RADIOLOGICAL EXAMINATIONS OF ABDOMEN OR PELVIS

Complete for all female patients age 12 to 55.
☐ No potential for pregnancy
☐ Pregnancy not suspected. Patient has been advised not to run a risk of pregnancy until two months after examination has been performed.
☐ Potential for pregnancy but postponement is not indicated.
☐ Pregnant; postponement to term is not indicated.
☐ Consider possibility of minimal examination.

Fig. 2. Guide for use in soliciting information from the patient concerning known or suspected pregnancy. [Modified from Brown *et al.*, 1974.]

of congenital defects regardless of radiation history (Brent and Gorson, 1972; Bolognese and Corson, 1975). For any individual case, the increased risk of such effects from doses below the 10-rad level received at any stage of pregnancy, according to the best knowledge available today, is very small when compared to this normal risk (Russell, 1957). Brent has pointed out that this small additional risk will be comparable with other risks which have been demonstrated epidemiologically, and which are not considered great enough to justify abortion (Brent and Gorson, 1972). For example, Stewart has estimated (Stewart and Kneale, 1968) that the increased risk of developing leukemia following the exposure of the fetus

to 2 rad is 1 in 2,000. This risk is smaller than the risk of leukemia in siblings of leukemics (1 in 720) (Miller, 1967).

There may be radiation dose levels, depending upon the stage of fetal-embryonic development (especially between the 10th day and 10th week postconception), above which there should be consideration of therapeutic abortion. However, it would be difficult to obtain agreement as to what these levels should be since so many factors must be taken into account. As Brent has stated (Brent and Gorson, 1972), "A decision as to whether to terminate the pregnancy will depend on (a) the hazard of the pregnancy to the expectant mother, (b) the extent and type of irradiation hazard to the embryo or fetus, (c) the ethnic and religious background of the family, (d) the laws of the state pertaining to legal abortion, and (e) any other relevant considerations." For example, if a woman (perhaps one who has finally conceived after much difficulty) wishes to see her pregnancy to term, she might wish to accept a certain risk of abnormality for her unborn child. This risk is considered to be negligible at 5 rad or less when compared to the other risks of pregnancy, and the risk of malformations is significantly increased above control levels only at doses above 15 rad. Therefore, the exposure of the fetus to radiation arising from diagnostic procedures would very rarely be cause, by itself, for terminating a pregnancy. If there are reasons, other than the possible radiation effects, to consider a therapeutic abortion, such reasons should be discussed with the patient by the attending physician, so that it is clear that the radiation exposure is not being used as an excuse for terminating the pregnancy.

3. Summary of Conclusions and Recommendations

Sensitivity to ionizing radiation is greater during intrauterine stages of development than at other stages in the life of the mammalian organism. For this reason, the NCRP recommends special care in patient selection in certain cases of diagnostic radiology and nuclear medicine diagnostic procedures. For women of child-bearing capacity, the physician requesting a radiological or nuclear medicine examination involving the lower abdominal or pelvic region should ascertain whether the patient is, or could be, pregnant. Figure 2 is a guide for documenting this information. Further, the NCRP recommends that physicians tell their premenopausal patients that, if they are likely to have nuclear medicine studies or x-ray examinations of the lower abdomen, it is generally advisable that they not run a risk of pregnancy until two months after the studies are carried out.

If, in the best judgment of the attending physician, a diagnostic examination or nuclear medicine procedure, *at that time*, is deemed advisable to the medical well-being of the patient, it should be carried out without delay, special efforts being made, however, to minimize the dose received by the lower abdomen (uterus). For example, such an examination should be conducted under conditions designed to limit the radiation exposure to the amount necessary for adequate examination. Filtration, collimation of the radiation beam to the anatomical region of interest, and careful selection of technical exposure factors can significantly contribute to good radiological practice and to the reduction of radiation exposure to all tissues. Such caution will automatically limit radiation effects on the embryo-fetus, if present. *Modification of an examination for dose reduction is warranted only if it reasonably can be done without significant jeopardy to the medical care of the patient and/or her unborn child.*

In the case of abdominal radiological or nuclear medicine irradiations of pregnant or potentially pregnant women that could be postponed without significantly jeopardizing the medical well-being of the patient, the physician should consider the fact that the probability of causing different types of effects varies with stage of pregnancy and with dose. Figure 1 is offered as a guide in making a decision whether the procedure should be postponed. The final decision to proceed or not to proceed with

the examination must depend on considerations of the patient's health, and on her wishes, and must reside with the attending physician in consultation with the radiological expert when such services are utilized; that is, the attending physician must retain full discretion to decide each case according to his judgment.

Experimental results obtained with high dose rate, low-LET radiation indicate that the probability of inducing malformations and/or growth retardation is greatest during the period of major organogenesis. In humans, the corresponding period probably starts 1 to 2 weeks after conception (3 to 4 weeks after the last menstruation) and extends through the 10th week postconception (12th week postmenses). For doses of less than 5 rad received at the period critical for the induction of any one specific type of mal-development, it is unlikely that an increase in this type of malformation could be measurable in human populations. Experimental results also indicate that irradiation during the pre-implantation period (in humans, the third and probably fourth weeks postmenstruation) does not result in malformations, but may lead to very early (asymptomatic) embryonic death. Not enough is known regarding the risks of leukemia and childhood cancer to draw any conclusions concerning relative magnitude of effect during different intrauterine stages.

A list of the various radiological examinations and the ranges of dose to the uterus that have been reported in the literature are shown in Table 1. The actual doses will depend upon the size of the patient, the extent of the examination and the technical factors used, and whether or not fluoroscopy is added to the radiographic examination. The figures given are only approximations.

A method is presented in Appendix A for determining the approximate dose to the uterus (fetus) from a radiographic examination, if the physical factors used for the study are known. The dose to the uterus from fluoroscopy is usually more difficult to estimate and one may find it advisable to consult with a qualified radiological physicist when fluroscopic examinations are involved.

APPENDIX A

Methods for Estimating the Dose to the Embryo-Fetus from Radiographic Examinations

The basic information that is required to estimate the dose to the embryo-fetus from radiographic examinations is the air exposure rate at some reference point and the half-value layer in millimeters of aluminum. If these data have not been measured for the x-ray machine and for the physical parameters (kVp, mA, filtration, beam size, source-skin distance) used, they may be estimated:

(1) The estimated exposure rate in air (mR/mAs) as a function of kVp and total aluminum filtration at 40″ (1 meter) from the x-ray source can be obtained from Figure 3, for three phase equipment, and from Figures 3 and 4, for single phase equipment.

(2) If the total filtration is known, the half-value layer (HVL) may be estimated from Table 2, for full-wave rectified potential x-ray machines, and from Table 3, for three phase and constant potential equipment. If the filtration and HVL are not known, for calculation purposes, assume a total filtration or a HVL of 2.5 mm of aluminum.

(3) By inverse square extrapolation, determine the exposure rate in air (i.e., without backscatter factor) at the source-skin distance (SSD) used (i.e., at the point where the primary beam enters the patient). Multiply the result by the total exposure in mAs and express the results in roentgens by dividing by 1,000.

(4) Use Table 4 to determine the estimated number of millirads to the uterus of a "standard woman" per roentgen exposure at the skin. For this table, the center of the uterus (and hence the fetus) is assumed to be located 8 cm below the anterior surface of the abdomen. This method works reasonably well for average-sized women in early pregnancy.

(5) If the patient is considerably larger or smaller than average, and/or if the patient is in the latter stages of pregnancy, a somewhat better

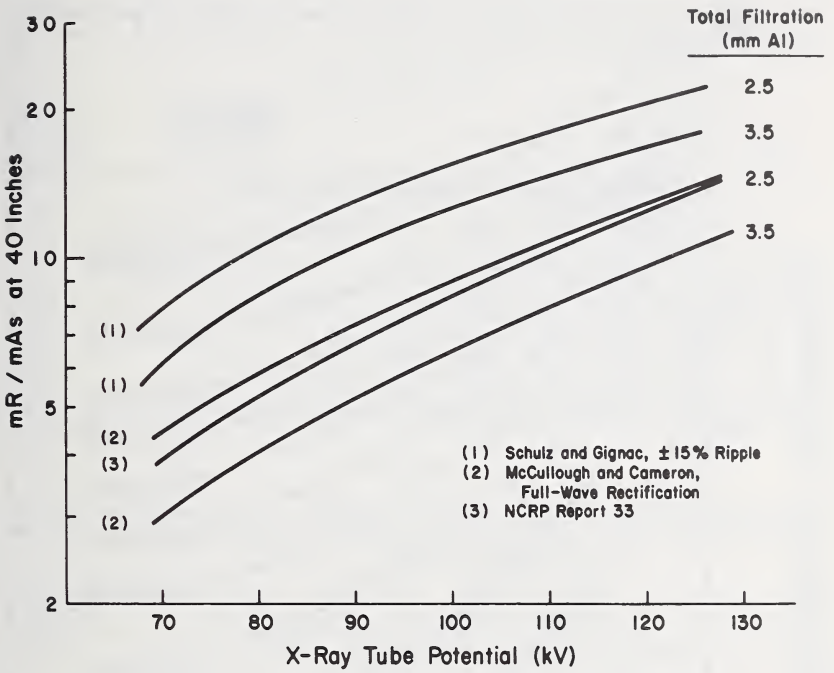

Fig. 3. Exposure rate in air (at 40 inches from the x-ray source) as a function of tube potential for various amounts of total aluminum filtration:
(1) Schulz and Gignac (1976), ± 15% ripple, three phase
(2) McCullogh and Cameron (1970), full-wave rectification, single phase
(3) NCRP Report No. 33 (NCRP, 1968), full-wave rectification, single phase

method is to use appropriate tissue-air-ratio (TAR) tables (Schulz and Gignac, 1976) for large fields at the depth (corresponding to the center of the uterus) below the skin where the beam enters the patient.

Example Calculation

An average-sized woman in early pregnancy undergoes radiological examinations including four AP radiographs of the pelvis. The pertinent physical parameters are as follows:
(1) Patient AP thickness is 26 cm
(2) Source to film distance (SSD) = 1 meter
(3) Tube potential setting = 80 kV, three phase generator
(4) Total filtration is 2.5 mm Al
(5) Tube current setting is 300 mA
(6) Exposure time per radiograph = 1/5 second

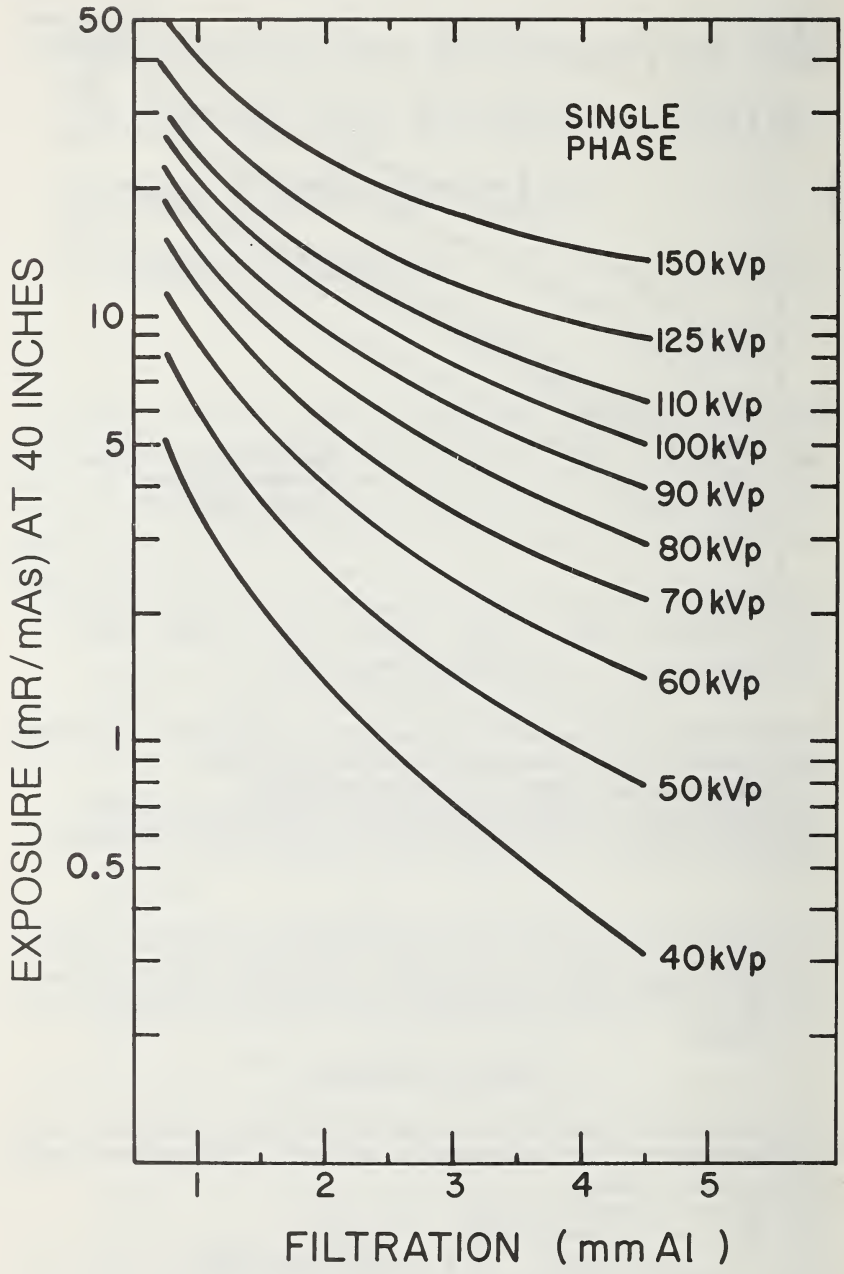

Fig. 4. Exposure rate in air (at 40 inches from the x-ray source) as a function of total filtration for various values of tube potential. Values are for full-wave rectified single phase equipment. [From McCullough and Cameron, 1970.]

TABLE 2—*Half-value layers as a function of filtration and tube potential for diagnostic units*[a]

Total Filtration mm Al	Peak Potential (kVp)									
	30	40	50	60	70	80	90	100	110	120
	Typical half-value layers in millimeters of aluminum									
0.5	0.36	0.47	0.58	0.67	0.76	0.84	0.92	1.00	1.08	1.16
1.0	0.55	0.78	0.95	1.08	1.21	1.33	1.46	1.58	1.70	1.82
1.5	0.78	1.04	1.25	1.42	1.59	1.75	1.90	2.08	2.25	2.42
2.0	0.92	1.22	1.49	1.70	1.90	2.10	2.28	2.48	2.70	2.90
2.5	1.02	1.38	1.69	1.95	2.16	2.37	2.58	2.82	3.06	3.30
3.0	—	1.49	1.87	2.16	2.40	2.62	2.86	3.12	3.38	3.65
3.5	—	1.58	2.00	2.34	2.60	2.86	3.12	3.40	3.68	3.95

[a]For full-wave rectified, single phase, potential. Derived from Hale (1966) by interpolation and extrapolation.

TABLE 3—*Half-value layer as a function of tube potential for three-phase generators*

Total Filtration mm Al	Peak Potential (kVp)								
	60	70	80	90	100	110	120	130	140
	Half-value layers in millimeters of aluminum								
2.5[a]	2.2	2.4	2.7	3.1	3.3	3.6	4.0	—	—
3.0[b]	2.3	2.6	3.0	3.3	3.6	4.0	4.3	4.6	5.0
3.5[a]	2.6	2.9	3.2	3.6	3.9	4.3	4.6	—	—

[a]Estimated from NCRP (1968) and Kelley and Trout (1971).
[b]From Kelley and Trout (1971).

Procedure

If no exposure rate and half value layer (HVL) data are available for the x-ray machine at the kVp and mA settings used, they may be estimated from Figure 3 and from Table 2.

(1) From Figure 3, at 80 kV, the exposure rate at 1 meter is approximately 10 mR/mAs for 2.5 mm total filtration, three phase equipment.

(2) From Table 3, for 80 kVp and 2.5 mm total filtration, the HVL is approximately 2.7 mm Al.

(3) The total exposure at 1 meter for the 4 radiographs is:

$$300 \text{ mA} \times \frac{1}{5} \text{ sec} \times 4 \times 10 \text{ mR/mAs} = 2400 \text{ mR} = 2.4 \text{ R}$$

(4) If we assume that there is a 2 cm distance between the patient and the film, the source to skin distance becomes:

$$\text{SSD} = 100 \text{ cm} - (26 \text{ cm} + 2 \text{ cm}) = 72 \text{ cm}$$

(5) The exposure in air at the SSD is:

$$\left(\frac{100}{72}\right)^2 \times 2.4 \text{ R} = 4.6 \text{ R}$$

(6) From Table 4, for AP pelvic projection, the dose to the uterus of an average sized woman is around 310 mrad per roentgen exposure at the skin, for a HVL of 2.7 mm Al by interpolation.
(7) Therefore, the estimated dose to the uterus (fetus in early pregnancy) is:
$D = 4.6\ R \times 310\ \text{mrad/R} = 1426\ \text{mrad} \cong 1.4\ \text{rad}$.

TABLE 4—*Embryo (uterine) doses for selected x-ray projections* (mrad/R)[a,b]

Projection	View	SID (inches)	Image Receptor Size (inches)[c]	Beam Quality (HVL, mm Al) 1.5	2.0	2.5	3.0	3.5	4.0
Pelvis, lumbopelvic	AP	40	17″ × 14″	142	212	283	353	421	486
	LAT	40	14″ × 17″	13	25	39	56	75	97
Abdominal[d]	AP	40	14″ × 17″	133	199	265	330	392	451
	PA	40	14″ × 17″	56	90	130	174	222	273
	LAT	40	14″ × 17″	13	23	37	53	71	91
Lumbar Spine	AP	40	14″ × 17″	128	189	250	309	366	419
	LAT	40	14″ × 17″	9	17	27	39	53	68
Hip	AP (one)	40	10″ × 12″	105	153	200	244	285	324
	AP (both)	40	17″ × 14″	136	203	269	333	395	454
Full Spine (Chiropractic)	AP	40	14″ × 36″	154	231	308	384	457	527
Urethrogram Cystography	AP	40	10″ × 12″	135	200	265	327	386	441
Upper G.I.	AP	40	14″ × 17″	9.5	16	25	34	45	56
Femur (one side)	AP	40	7″ × 17″	1.6	3.0	4.8	6.9	9.4	12
Cholecystography	PA	40	10″ × 12″	0.7	1.5	2.6	4.1	6.0	8.3
Chest	AP	72	14″ × 17″	0.3	0.7	1.3	2.0	3.1	4.3
	PA	72	14″ × 17″	0.3	0.6	1.2	2.0	3.0	4.5
	LAT	72	14″ × 17″	0.1	0.3	0.5	0.8	1.2	1.8
Ribs, Barium Swallow	AP	40	14″ × 17″	0.1	0.3	0.5	0.9	1.4	2.0
	PA	40	14″ × 17″	0.1	0.3	0.5	0.9	1.5	2.2
	LAT	40	14″ × 17″	0.03	0.08	0.2	0.3	0.4	0.6
Thoracic Spine	AP	40	14″ × 17″	0.2	0.4	0.8	1.4	4.1	3.0
	LAT	40	14″ × 17″	0.04	0.1	0.2	0.4	0.5	0.8
Skull, Cervical Spine, Scapula, Shoulder, Humerus	—	40	—	<.01	<.01	<.01	<.01	<.01	<.01

[a]Average dose to the uterus (mrad) for 1 roentgen entrance skin exposure (free-in-air).
[b]From Rosenstein (1976).
[c]Field size is collimated to the image receptor size.
[d]Includes: Retrograde Pyelogram, KUB, Barium Enema, Lumbosacral Spine, IVP, Renal Arteriogram.

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No. Title and Author

1 *The Squares of the Natural Numbers in Radiation Protection* by Herbert M. Parker (1977)

2 *Why be Quantitative About Radiation Risk Estimates?* by Sir Edward Pochin (1978)

3 *Radiation Protection—Concepts and Trade Offs* by Hymer L. Friedell (1979) [Available also in *Perceptions of Risk,* see above]

4 *From "Quantity of Radiation" and "Dose" to "Exposure" and "Absorbed Dose"—An Historical Review* by Harold O. Wyckoff (1980) [Available also in *Quantitative Risks in Standards Setting,* see above]

5 *How Well Can We Assess Genetic Risk? Not Very* by James F. Crow (1981) [Available also in *Critical Issues in Setting Radiation Dose Limits,* see above]

6 *Ethics, Trade-offs and Medical Radiation* by Eugene L. Saenger (1982) [Available also in *Radiation Protection and New Medical Diagnostic Approaches,* see above]

7 *The Human Environment-Past, Present and Future* by Merril Eisenbud (1983) [Available also in *Environmental Radioactivity,* see above]

8 *Limitation and Assessment in Radiation Protection* by Harald H. Rossi (1984) [Available also in *Some Issues Important in Developing Basic Radiation Protection Recommendations,* see above]

9 *Truth (and Beauty) in Radiation Measurement* by John H. Harley (1985) [Available also in *Radioactive Waste,* see above]

10 *Nonionizing Radiation Bioeffects: Cellular Properties and Interactions* by Herman P. Schwan (1986) [Available also in *Nonionizing Electromagnetic Radiations and Ultrasound,* see above]

11 *How to be Quantitative about Radiation Risk Estimates* by Seymour Jablon (1987) [Available also in *New Dosimetry at Hiroshima and Nagasaki and its Implications for Risk Estimates,* see above]

12 *How Safe is Safe Enough?* by Bo Lindell (1988) [Available also in *Radon,* See above]

13 *Radiobiology and Radiation Protection: The Past Century and Prospects for the Future* by Arthur C. Upton (1989)

NCRP Commentaries

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1	*Krypton-85 in the Atmosphere—With Specific Reference to the Public Health Significance of the Proposed Controlled Release at Three Mile Island* (1980)
2	*Preliminary Evaluation of Criteria for the Disposal of Transuranic Contaminated Waste* (1982)
3	*Screening Techniques for Determining Compliance with Environmental Standards* (1986), Rev. (1989)
4	*Guidelines for the Release of Waste Water from Nuclear Facilities with Special Reference to the Public Health Significance of the Proposed Release of Treated Waste Waters at Three Mile Island* (1987)
5	*Living Without Landfills* (1989)

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No.	Title
8	*Control and Removal of Radioactive Contamination in Laboratories* (1951)

22 *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure* (1959) [Includes Addendum 1 issued in August 1963]
23 *Measurement of Neutron Flux and Spectra for Physical and Biological Applications* (1960)
25 *Measurement of Absorbed Dose of Neutrons and Mixtures of Neutrons and Gamma Rays* (1961)
27 *Stopping Powers for Use with Cavity Chambers* (1961)
30 *Safe Handling of Radioactive Materials* (1964)
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41 *Specifications of Gamma-Ray Brachytherapy Sources* (1974)
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44 *Krypton-85 in the Atmosphere—Accumulation, Biological Significance, and Control Technology* (1975)
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50 *Environmental Radiation Measurements* (1976)
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53 *Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally Exposed Women* (1977)
54 *Medical Radiation Exposure of Pregnant and Potentially Pregnant Women* (1977)
55 *Protection of the Thyroid Gland in the Event of Releases of Radioiodine* (1977)
57 *Instrumentation and Monitoring Methods for Radiation Protection* (1978)
58 *A Handbook of Radioactivity Measurements Procedures*, 2nd ed. (1985)

59 *Operational Radiation Safety Program* (1978)
60 *Physical, Chemical, and Biological Properties of Radiocerium Relevant to Radiation Protection Guidelines* (1978)
61 *Radiation Safety Training Criteria for Industrial Radiography* (1978)
62 *Tritium in the Environment* (1979)
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The following NCRP Reports are now superseded and/or out of print:

No.	Title
1	*X-Ray Protection* (1931). [Superseded by NCRP Report No. 3]
2	*Radium Protection* (1934). [Superseded by NCRP Report No. 4]
3	*X-Ray Protection* (1936). [Superseded by NCRP Report No. 6]
4	*Radium Protection* (1938). [Superseded by NCRP Report No. 13]
5	*Safe Handling of Radioactive Luminous Compounds* (1941). [Out of Print]
6	*Medical X-Ray Protection Up to Two Million Volts* (1949). [Superseded by NCRP Report No. 18]
7	*Safe Handling of Radioactive Isotopes* (1949). [Superseded by NCRP Report No. 30]

9 *Recommendations for Waste Disposal of Phosphorus-32 and Iodine-131 for Medical Users* (1951). [Out of Print]

10 *Radiological Monitoring Methods and Instruments* (1952). [Superseded by NCRP Report No. 57]

11 *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water* (1953). [Superseded by NCRP Report No. 22]

12 *Recommendations for the Disposal of Carbon-14 Wastes* (1953). [Superseded by NCRP Report No. 81]

13 *Protection Against Radiations from Radium, Cobalt-60 and Cesium-137* (1954). [Superseded by NCRP Report No. 24]

14 *Protection Against Betatron—Synchrotron Radiations Up to 100 Million Electron Volts* (1954). [Superseded by NCRP Report No. 51]

15 *Safe Handling of Cadavers Containing Radioactive Isotopes* (1953). [Superseded by NCRP Report No. 21]

16 *Radioactive Waster Disposal in the Ocean* (1954). [Out of Print]

17 *Permissible Dose from External Sources of Ionizing Radiation* (1954) including *Maximum Permissible Exposure to Man, Addendum to National Bureau of Standards Handbook 59* (1958). [Superseded by NCRP Report No. 39]

18 *X-Ray Protection* (1955). [Superseded by NCRP Report No. 26]

19 *Regulation of Radiation Exposure by Legislative Means* (1955). [Out of Print]

20 *Protection Against Neutron Radiation Up to 30 Million Electron Volts* (1957). [Superseded by NCRP Report No. 38]

21 *Safe Handling of Bodies Containing Radioactive Isotopes* (1958). [Superseded by NCRP Report No. 37]

24 *Protection Against Radiations from Sealed Gamma Sources* (1960). [Superseded by NCRP Report Nos. 33, 34, and 40]

26 *Medical X-Ray Protection Up to Three Million Volts* (1961). [Superseded by NCRP Report Nos. 33, 34, 35, and 36]

28 *A Manual of Radioactivity Procedures* (1961). [Superseded by NCRP Report No. 58]

29 *Exposure to Radiation in an Emergency* (1962). [Superseded by NCRP Report No. 42]

31 *Shielding for High Energy Electron Accelerator Installations* (1964). [Superseded by NCRP Report No. 51]

33 *Medical X-Ray and Gamma-Ray Protection for Energies up to 10 MeV*—Equipment Design and Use (1968). [Superseded by NCRP Report No. 102]

34 *Medical X-Ray and Gamma-Ray Protection for Energies Up to 10 MeV—Structural Shielding Design and Evaluation* (1970). [Superseded by NCRP Report No. 49]

39 *Basic Radiation Protection Criteria* (1971). [Superseded by NCRP Report No. 91]

43 *Review of the Current State of Radiation Protection Philosophy* (1975). [Superseded by NCRP Report No. 91]

45 *Natural Background Radiation in the United States* (1975). [Superseded by NCRP Report No. 94]

48 *Radiation Protection for Medical and Allied Health Personnel* [Superseded by NCRP Report No. 105]

56 *Radiation Exposure from Consumer Products and Miscellaneous Sources* (1977). [Superseded by NCRP Report No. 95]

58 *A Handbook on Radioactivity Measurement Procedures.* [Superseded by NCRP Report No. 58, 2nd ed.]

Symposium Proceedings

The Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack, Proceedings of a Symposium held April 27–29, 1981 (1982)

Other Documents

The following documents of the NCRP were published outside of the NCRP Reports and Commentaries series:

"Blood Counts, Statement of the National Committee on Radiation Protection," Radiology 63, 428 (1954)

"Statements on Maximum Permissible Dose from Television Receivers and Maximum Permissible Dose to the Skin of the Whole Body," Am. J. Roentgenol., Radium Ther. and Nucl. Med. 84, 152 (1960) and Radiology 75, 122 (1960)

Dose Effect Modifying Factors In Radiation Protection, Report of Subcommittee M-4 (Relative Biological Effectiveness) of the National Council on Radiation Protection and Measurements, Report BNL 50073 (T-471) (1967) Brookhaven National Laboratory (National Technical Information Service, Springfield, Virginia).

X-Ray Protection Standards for Home Television Receivers, Interim Statement of the National Council on Radiation Protection and Measurements (National Council on Radiation Protection and Measurements, Washington, 1968)

Specification of Units of Natural Uranium and Natural Thorium (National Council on Radiation Protection and Measurements, Washington, 1973)

NCRP Statement on Dose Limit for Neutrons (National Council on Radiation Protection and Measurements, Washington, 1980)

Control of Air Emissions of Radionuclides (National Council on Radiation Protection and Measurements, Bethesda, Maryland, 1984)

Copies of the statements published in journals may be consulted in libraries. A limited number of copies of the remaining documents listed above are available for distribution by NCRP Publications.

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